ARE THE INTESTINES ABLE TO PROPEL THEIR CONTENTS IN AN ANTI-PERISTALTIC DIRECTION? *

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IN the following pages we wish to bring together some of the evidence in favor of an affirmative answer to the above query. The evidence in favor of such an anti-peristaltic movement is both clinical and experimental. How frequently under normal conditions such movements do occur in the human intestine remains to be determined by future investigation. Here we are concerned only with the question, can the intestines propel their contents in an anti-peristaltic direction?

That this question is not altogether simple is evident. That it is not settled will be readily gathered from the statements to be quoted from recent authoritative writers. In Wilms' book on Ileus just published (on p. 26) he states, " An anti-peristalsis, that is, an evident upward peristalsis driving the contents of the bowel towards the pylorus, and not towards the anus, does not occur." On the other hand, W. J. Mayo, American Journal of the Medical Sciences, January, 1907 (p. 4), states, " The normal action of the upper colon is anti-peristaltic except during defecation," and further, " Murphy has shown that salines introduced very slowly into the rectum will be absorbed with great rapidity, largely by reverse peristalsis to the cecum." These opposed views, recently expressed, show the need of further study along these lines, and we trust that the following array of evidence will convince

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many who at present agree with Wilms' in his statement of the case.

Before discussing the evidence gleaned from experiments in the laboratory, and from observations in the clinic, we must briefly analyze a phenomenon which in all probability does not concern this study. If some non-absorbable powder, such as carmine, be placed within the rectum of a patient with a colostomy opening, and smears be made from this artificial anus, one will almost regularly find, in a shorter or a longer time, granules of this powder. In other words, this carmine has wandered from the rectum up the bowel and out through the colostomy wound. This curious phenomenon can be observed by any one in such clinical material as above referred to, or in laboratory animals if desired. At first blush it looks like an affirmative reply to the question before us, for the contents of the rectum have wandered upwards in an anti-peristaltic direction. Perhaps in due time this phenomenon may be adequately explained. At present almost all investigators are inclined to interpret this upward wandering of carmine from the rectum to the colon, or even to the stomach or higher, as due to upward currents along the intestinal wall, quite independent of peristalsis. The fact that this phenomenon occurs despite stenoses of the bowel, the carmine wandering through these rigid parts, and the fact that intestinal quiet favors the ascent of the carmine seem to exclude this from the group of phenomena which point to the possibility of anti-peristaltic activity in the intestine. The final verdict, however, has not been reached as yet.

Of direct bearing on the question before us, are two groups of observations—the one gathered in the laboratory and the other in the clinic. Both are of great importance, and both must be analyzed carefully. The experimental work is the more important as the observations are fuller and perhaps more accurate, and these we shall take up first, leaving clinical evidence for later consideration.

There are two experimental methods of approaching the problem as to whether the intestine is capable of propelling its contents in the reversed or anastaltic direction, and in our work, which has been in progress almost 1½ years, we have employed only one of these, and that which seemed to promise most to us. Instead of employing the method of direct observation of the unoperated bowel, with or without the use of the X-rays we have used the operative or functional method of testing the capacity of the intestine for working in the reversed direction, by resecting segments in the small and large bowel, turning them around, and sewing them in place in reverse position. If the bowel is capable of propelling food in the reverse direction, then this reversed piece of intestine will function isoperistaltically; in other words its normal downward peristalsis will give way from time to time, or altogether to what would, under normal conditions, be anti-peristalsis. Thus we would acquire rather conclusive proof that the intestine is capable of doing anti-peristaltic work, of accomplishing what Wilms so recently denied.

This method of approaching our problem is by no means original, as in 1889, Kirstein attacked the question of anti-peristalsis in just this way. Since his publication many others have repeated his experiments (Mall, Edmunds and Balance, Muehsam, Kelling, Kauders, Enderlen and Hess, Prutz and Ellinger), but the lack of uniformity in results has occasioned considerable confusion.

Wilms' recent statement that, " in the experiments of Prutz and Ellinger, who have again carefully analyzed the anti-peristaltic intestinal movements, it is conclusively proven that the reversed segment shows the same peristalsis as before reversal, and that no real anti-peristalsis develops," fails to throw any light on this subject; in fact in our opinion, adds to the difficulties already existing. A brief review of the published work, and a careful analysis of Prutz and Ellinger's experiments will show, we believe, how erroneous Wilms' conclusion is.

In our opinion, the most satisfactory method of arriving at well-founded conclusions in these reversal experiments is by the direct study of the behavior of the reversed loops. That is the only sure way of deciding in which direction the peristaltic waves progress. A second, but less accurate and decidedly inferential method of arriving at valid conclusions, is that in which reversals of extensive segments of the bowel are made. In such animals, regular defecations must be the sign of downward or katastaltic waves, as one cannot conceive of the intestinal contents traversing very large segments of reversed bowel towards the anus, unless the peristaltic waves propel them in that direction.

With these two methods and view points in mind, let us briefly review the work done along these lines, and then take up our own experiments which were done in part by ourselves, and in part by the students of the College of Physicians and Surgeons under the careful supervision of Dr. Maury.

A. Kirstein[1]—1889—operated on two dogs, reversing segments of the small intestine. He attempted a direct study of the peristalsis in one of his animals, but his attempt was unsuccessful. He noted at autopsy, the animals being killed 7 weeks and 3 months, respectively, after the operation, that at the upper anastomosis there was a spindle shaped dilatation with hypertrophy extending above and below the upper end to end anastomosis, and bisected by this. This dilatation he explained as the result of the two peristaltic waves working against each other. He concluded, with perfect propriety, that the peristalsis in the reversed gut must be reversed at least from time to time, to allow of the downward passage of intestinal contents through a reversed segment, which was ¼ of the length of the total small bowel, as in his second experiment.

Mall's[2] work was done about the same time as Kirstein's. He also found that at the upper anastomosis there regularly developed dilatation and hypertrophy, and that in this spindle shaped area, hard foreign bodies tended to collect, though some glass balls fed to such an animal passed through the whole alimentary tract. Faradic stimulation (2 mos. p. op.) in one case in which he employed it, showed no reversal of the peristaltic waves.

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[1] Deutsche Medizinische Wochenschrift, p. 1000, 1889.

[2] Johns Hopkins Hospital Reports, p. 93, 1896.

F. Kauders[3]—1893—repeated these reversal experiments in cats, but failed to obtain any adequate results from his study of the peristalsis of the reversed loop, as only the circular muscle fibres contracted. He thought that Kirstein's conclusions were incorrect, that the bowel contents were squirted through the reversed loop which was passive. He made this more than bold criticism despite the fact that in Kirstein's case (No. 2) ¼ of the small gut was reversed. To imagine a force adequate to squirting food, etc., through ¼ of the length of the small bowel, requires more than an ordinary effort.

W. Edmunds and C. A. Ballance[4]—1896—repeated these reversal experiments, and though their work throws no light on the question of anti-peristalsis, they call attention to the fact that the reversed loop became shorter in their cases.

G. Kelling[5]—1900—published one reversal operation in the uppermost jejunum. Three and one-third months after this operation he opened the animal's abdomen, and made a more or less satisfactory study of the peristalsis of the reversed loop. He incised the lower end of the loop, and saw the contents moved towards the rectum by distinct peristaltic waves! This animal was alive and well 1⅓ years after the operation.

Muehsam[6]—1900—contributed a great deal to this subject by bringing further evidence based on the second method of studying this problem—evidence along the same lines as Kirstein's, but perhaps more conclusive. He reversed practically all the small gut (430 cm. out of 485 cm.), and the animal lived 22 days, having occasional attacks of vomiting, and regular defecations. In the defecations, he recovered charcoal which had been fed by mouth 18 hours earlier. This unique case can in our opinion, be explained in only one way, by a reversal of the peristalsis in the reversed intestine.

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[3] Centralblatt f. Physiologie, p. 222, 1893.

[4] Medico-Chirurgical Transactions, London, vol. 76, 1896.

[5] Langenbeck's Archiv., p. 326, Bd. 62, 1900.

[6] Mittheilungen aus d. Grenzgebieten d. Medizin u. Chirurgie, vol. 6, 1900.

(*Prutz and Ellinger* try to explain the phenomena here observed as the result of the action of the surface currents originally described by Grützner, to which reference has been made above.)

In 1901 *Enderlen and Hess*[7] experimented along these lines, and in one case made a study of the peristalsis in the reversed loop. By faradic stimulation, a peristaltic wave was produced in the reversed direction from normal, *i.e.*, the peristaltic wave was reversed in the reversed loop.

In 1902, Prutz and Ellinger[8] reviewed the whole subject, and did further experimental work along the same lines. In one case they observed the peristalsis in the reversed loop, 31 days after the operation, and found that it was not reversed. They admit, however, that occasionally anti-peristaltic (reversed) waves were seen in the reversed, and in the non-reversed bowel. In all their 12 experiments this is the only observation or study of the peristalsis of the reversed loop. They, however, attempted to determine by other means, in which direction the peristaltic wave progressed. By producing a stenosis in the lower part of the reversed loop, and noting on which side of this, dilatation developed, they thought they could discover the direction of the wave. Thus if the peristalsis were reversed, dilatation would occur above the stenosis; if not reversed, dilatation would develop below the artificial stenosis. In 2 cases they obtained results which they interpret as showing no reversal of the peristaltic wave. In our opinion, they have gone beyond the data which they have published, and to us it seems as if their conclusion was not only unwarranted, but in view of the fact that the dilatation above the artificial stenoses was regularly much greater than that below, a conclusion, the direct opposite of theirs, seems justifiable.

This brief review shows how at variance the different results are. Most of the experimentors failed to study the peristalsis in the reversed loop. Some attempted such a study, but invariably only in one case. This most conclusive method of deciding the problem before us has been signally neglected. The second method of investigating this question, Kirstein and Muehsam used successfully by making very extensive reversals.

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[7] Deutsche Zeitschrift f. Chirurgie, p. 240, 1901.

[8] Langenbeck's Archiv., p. 964 Bd. 67, 1902.

In our work done on dogs, some 20 experiments in all, we employed both methods of investigation, and our results will be grouped according to the method employed. We operated in the usual way, cutting out a segment of small gut or large gut and then reversing it. The anastomoses were either end to end, or lateral. The latter was preferable when very large segments were reversed, as there was apparently, less direct tension on the suture line by opposed peristaltic waves, and consequently less chance of leakage. No matter how carefully the operation was done, leakage and separation at the upper anastomosis would occasionally develop so that we were inclined to conclude that the bowels of different dogs varied in their irritability, and perhaps in their muscular strength to such a degree that the technique that was adequate for one might prove inadequate for another, when the opposing and perhaps obstructive peristaltic waves caused undue pressure against the upper anastomosis. At the lower anastomosis, such leakage was most exceptional despite the fact that the direction of the peristaltic waves was probably in opposite directions, *i.e.*, tugging at the anastomosis.

In all animals that survived the operation, we did not make studies in peristalsis, as we were interested in other problems connected with this work, and did not wish to sacrifice all to this study. In the following pages we trust, however, we have sufficient data to warrant the standpoint we have taken.

SERIES I.—*Direct Inspection of Reversed Loop—Small Intestine Reversals.*

No. 84.—Spaniel operated March 15, '06. Median abdominal incision. Reversal of about 15 inches of lower ileum and lateral anastomoses in reversed position, to the bowel above and below lines of section.

March 20. After primary indisposition animal recuperated on diet of milk and biscuits.

May 20. Defecates regularly (practically daily; careful note of this being made every day). Animal began to do poorly.

June 9. Eleven weeks after the reversal a study of the peristalsis was made under ether, the intestines being well protected by very frequent use of warm saline solution, hot towels, etc. The peristaltic waves were stimulated in a variety of ways, mechanical, chemical and thermal stimuli being employed in the different experiments.

Observation.—The peristaltic wave in the reversed loop was very clearly in the same direction as that of the rest of the small bowel. Peristaltic waves that began above upper anastomosis traveled into the reversed loop and then down this across the lower anastomosis. Peristaltic waves which began in the reversed loop traveled to a slight extent upward, but in the main they traveled downward and then frequently across the lower anastomosis.

Autopsy showed in addition to some adhesions which produced slight kinking of the bowel, well marked dilatation and some hypertrophy of the lower end of the gut above the upper lateral anastomosis. The reversed piece was very slightly dilated and contained two large fecal masses.

No. 41.—Fox terrier had been frequently operated, *i.e.*, gastroenterostomy, gastrotomy before reversal was done.

March 8. After breaking up a lot of adhesions 24 inches of lower ileum were reversed and united to the rest of the bowel by end to end anastomoses.

April 1. Animal except for occasional vomiting did fairly well. By adding milk to his biscuit diet his condition was improved. Defecates regularly.

April 24. Six weeks and five days after the reversal the abdomen was opened to study the peristalsis as in the previous case. The exposure was difficult because of adhesions.

Observation.—The bowel proximal to the upper end to end anastomosis was found markedly dilated and hypertrophied for 6–8 inches. The upper part of the reversed gut for 1–2 inches was similarly changed. The rest of the reversed bowel—the lower anastomosis and the bowel below were unchanged. The reversed loop was empty, whereas the parts adjacent to the upper anastomosis were full of intestinal contents. In studying the peristaltic waves great difficulty was met with in determining which way they progressed. Above the upper anastomosis the wave was katastaltic, *i.e.*, in the normal direction, while in the reversed loop mechanical stimulation as well as heat evoked once a peristalsis in one direction and at another time in the opposite direction. In the lower part of the reversed loop the direction of the peristaltic wave was more distinctly downward. Abdomen closed.

May 12. Nine weeks and two days after reversal, abdomen again opened for peristaltic study.

Observation.—After separating adhesions in abdomen, we attempted to stimulate peristalsis without any further manipulation of the bowel. Croton oil was injected into the lumen without results; local application of salt produced only localized circular contractions. Hot saline solution produced well-marked peristaltic waves, which could be seen beginning above the upper anastomosis, traveling across this anastomosis and continuing down the reversed gut. In this loop the circular muscle contractions were well marked. The progression of the peristaltic waves were distinctly from upper to lower anastomosis. The bowel was almost empty. Animal killed.

No. 90. Pug. On March 22d between 12 and 15 inches of lower ileum were reversed and end to end anastomoses (Maunsell method) were made. The dog was carefully fed on milk, meat and biscuits so that he might continue in good health for a long time.

October 23. Seven months after the reversal the abdomen was opened.

Observation.—There was marked dilatation above upper union for at least 15 inches. This piece of bowel was also hypertrophied. In the region of the upper anastomosis there was an accumulation of stones. The reversed loop was slightly dilated and markedly hypertrophied. The peristaltic waves were distinctly downward in the reversed loop.

SERIES II.—*Colon Reversals.*

No. 76.—On March 10, 1906, as much of the ascending colon as could be liberated—about 6 inches—was resected and reversed and then reunited by end to end anastomoses to the rest of the bowel. This case did well on the selected diet.

January 4, 1907. Almost ten months after operation the abdomen was opened and a study of the peristalsis was made.

Observation.—The reversed loop was dilated and hypertrophied. The peristaltic waves descend from the ileum across the upper anastomosis and then descend through the reversed loop, but stop at the lower anastomosis. Circular contractions follow each other in the reversed loop, in the same direction as the composite peristaltic wave. The reversed bowel contains foreign bodies.

These observations of the behaviour of the reversed loops leave no doubt in our minds that the small and the large bowels are capable of propelling food in an anti-peristaltic direction. It would appear that the bowel has a distinct power to work in an anti-peristaltic direction and moreover that this power is capable of extensive development. Early in the life of the reversed loop, there seem to be ana- and kata-staltic waves; later on the kata-staltic (which are anti-peristaltic with reference to the original normal bowel) seem to predominate. We are inclined to agree with Kirstein, that in the reversed loop, the peristaltic waves vary in direction, especially at an early stage in the life of the reversed loop, and that is well shown by Case 41, at the first study of peristalsis. Prütz and Ellinger's observation of anti-peristaltic alternating with isoperistaltic waves in their one case, seems to us to fit into this view of the matter. Perhaps Mall's observation will bear a similar interpretation which harmonizes the divergent results summarized above. To what extent the reversed bowel moves kata-staltically with abdomen closed, we can not say as yet.

Just why a more or less spindle-shaped dilatation develops at the upper union is not very clear to us. At first one would jump at the explanation usually offered—that there is an obstruction due to opposed peristaltic waves and that leads to dilatation and hypertrophy at this point.[9]

That some truth is contained in this explanation, in view of the fact that foreign bodies tend to collect in the lumen at this point, and in view of the observation made by Cannon and Murphy mentioned further on, we can not doubt, though we feel sure it is not the complete explanation, as the same obstruction would, we think, be manifested throughout the length of the reversed loop, still the loop as a whole does not dilate and hypertrophy.[10]

If we now turn our attention to the second or inferential method, *i.e.*, the reversal of very big segments of the bowel, we find that with reversal of the whole jejunum and ileum, most animals die of a perforative peritonitis due to leakage at the upper union. Those animals that live long enough to be of any value, behave much as Muehsam's case, defecating repeatedly after the first day or two, without any marked vomiting. These animals, probably because of the great change in the intestinal chemistry, digestion and absorption being rudely interfered with, die very suddenly. For instance, one animal thus operated on did well in every respect for five days and then died suddenly without any definite gross lesions to demonstrate the cause. Another died suddenly 10 days after operation, a few hours after receiving a good dose (½ ounce) of castor oil. This animal at autopsy had a fresh invagination at the lower anastomosis which occluded the bowel.

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[9] The fact that this dilatation develops very early lends support to this view.

[10] The colon may behave differently from the small intestine—the whole loop apparently dilates and hypertrophies here.

But it is not necessary to rely on such extreme cases alone. It is sufficient to reverse some 15–24 inches, as we did in a large number of cases. For it is inconceivable that an animal can defecate regularly, if such a length of reversed bowel does not, at least from time to time, function kata-staltically. In the cases quoted above, such resections have been made and the animals lived in fairly good health and defecated practically every day, provided they were carefully fed. To cite further cases, from our lists, of prolonged life with regular bowel activity after such reversals would not be of any value. We regret that we could not duplicate Muchsam's case and keep an animal, with reversal of all the small intestine, alive for over three weeks.

Thus both groups of observations point to the conclusion that the intestines both large and small, are able to propel their contents in an anti-peristaltic direction.

Further evidence of the truth of this conclusion is furnished by the excellent observations of Cannon andMurphy,[11] who observed anti-peristalsis in the duodenum, a portion of the intestine that we could not experiment on. In a reversal experiment, where the jejunum was reversed close to the duodenum, they repeatedly saw, 6 days after operation, with the aid of the X-ray, that food left the pylorus and descended to the upper anastomosis and then was in part rapidly moved back again towards the pylorus. This unique observation makes it equally clear that there is a more or less marked obstructive condition at the upper anastomosis in these reversal experiments.

Cannon's earlier work on the peristalsis of the ascending colon of cats, shows without a doubt that Jacobi's [12] observation of anti-peristalsis in this part of the bowel (and in lower ileum in colchicin poisoning) was well founded. Here it would seem that this is a normal process,[13] whereas our experiments do not take us that far, any more than those well known experiments of Nothnagel, in which he produced antiperistalsis in the bowels by abnormal stimuli, such as injections of concentrated salt solution.

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[11] ANNALS OF SURGERY, 1906.

[12] Archiv. f. Exp. Pathologie u. Pharmakologie, vol. xxvii, 1890.

[13] Except in dogs. T. R. Elliott and E. Barclay Smith, Journal of Physiology, xxxi, 1904, p. 273.

In addition to all this experimental evidence, we dare not disregard the clinical evidence which so frequently has to be taken with a grain of salt. In this paper we shall not go into this matter in any great detail, as our main object was to present our experimental results; still for completeness sake we must briefly mention the clinical evidence in favor of an affirmative answer to our postulated query, at the head of this paper.

Fecal vomiting in intestinal obstruction and the vomiting of fecal masses and enemata in so called hysterical patients, excluding of course actual cases of fraud can be most readily explained by this ability of the bowel, especially marked under abnormal stimuli of propelling their contents in an anastaltic or antiperistaltic direction.

These two types of fecal vomiting must be distinctly separated, as the former is explicable in several ways whereas the latter in our opinion is subject to but one explanation. In the vomiting of intestinal obstruction, the fluid contents of the bowel may be squeezed out of the bowel into the stomach, thence to the outer world by the pressure exerted by the forceful contractions of the abdominal muscles—anti-peristalsis may have nothing to do with it. Cannon and Murphy's observation, above referred to, makes us believe however, that antiperistalsis is an important factor in this process, the more so as all of the bowel above an obstruction is not regularly well filled at autopsy of ileus cases, as the explanation based on hydrodynamics would demand. It appears to us, therefore, that both forces work together in producing this symptom.

The vomiting of formed feces and the vomiting of enemata a few minutes after introduction into a normal alimentary tract, as reported by Treves, Langmann [14] and others, cannot be explained by anything short of a most active antiperistalsis of the whole bowel. In this we consider Nothnagel's verdict final, despite Wilms' recently expressed scepticism. The former says in his discussion of those cases, so called hysterical ileus cases, " that in no other way can this vomiting be effected than by well marked, in part even very active antiperistalsis of the intestine."

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[14] A. Jacobi, Festschrift, 1900, N. Y.